Appendix B.
Post-hooking survival studies

In biological opinions on the effects of fisheries on the survival of sea turtles, NMFS has to include an assessment of the survival of turtles that have been hooked and released. Although data on post-hooking survival is limited, recent satellite-tagging studies in Hawaii and the Azores have yielded useful data on short- and long-term survival of turtles that had ingested hooks and were released. At the same time, the results of these studies are difficult to interpret and lead to conflicting conclusions. Nevertheless these data are summarized below (for a more complete discussion of these data, see Appendix 4 of NMFS SEFSC 2001).

Studies Conducted in Hawaii.

From 1997 to late 2000, a total of 49 pelagic turtles hooked by the Hawaii-based longline fishery have had satellite transmitters attached to them in order to track their location and distance traveled following the interaction. Of these 49 turtles, 15 produced no transmissions, or their transmissions lasted less than a month[1] - 11 had deeply ingested hooks (turtles had swallowed the hook, and it was not removed) and 4 were lightly hooked.(turtles had the hook lodged externally (beak or flipper), permitting easy removal) (D. Parker and G. Balazs, NMFS, pers. comm., November 2000). No assumptions were made regarding the fate of these turtles that failed to transmit or only transmitted for a short period of time. Assuming that the satellite transmitter was working correctly, there are a number of possible explanations for little or no transmissions, any of which could be correct. After being hooked, forcibly submerged, hauled with the longline gear, and brought aboard a vessel, a turtle may not have had time to recover from any injuries before it was released.

As discussed previously, turtles need time at the ocean's surface to process lactic acids that have accumulated because of high levels of activity; processing lactic acid requires the turtle's to use their energy reserves. Sea turtles that have been released after being captured often appear to be moving fairly well and then just collapse, while they rebuild their energy stores or repay their oxygen debt (E. Jacobsen *in* Balazs *et al*. 1995). If a turtle does not have enough energy to remain afloat, it will probably sink and drown. In addition, a turtle that has been released may later die from injuries it sustained as a result hooking, especially if a hook has perforated one of its organs. In either instance, a turtle would sink with its transmitter and no signal would be received. With the data available, it is impossible to determine if these turtles sank and died, or if the transmitters simply failed to transmit.

For the 34 turtles that produced successful tracks that lasted more than a month, there were no

[1] Of these 15 turtles, only 4 (all loggerheads) did actually produce transmissions lasting 0, 1, 6, and 13 days, traveling 13, 46, 161, and 354 kilometers, respectively. The rest (n=9) did not produce any transmissions (D. Parker and G. Balazs, NMFS, personal communication, September, 2000).

significant differences (P>0.05) found for the duration of tracking (days) and the distance traveled between lightly hooked turtles (n=15) and turtles with deeply ingested hooks (n=19). Even when the 15 turtles that did not produce successful tracks were taken into account, no significant differences were found in terms of distance traveled and duration between the two groups (19 total lightly hooked, and 30 total deeply ingested). Furthermore, when species were analyzed individually for the two categories, no significant differences were found.

Polovina (NMFS, pers. comm., September, 2000) used a contingency table approach to analyze the transmission duration in intervals of 1 month for 34 loggerheads (including those with few or no transmissions), comparing lightly hooked versus deeply hooked turtles. While 43% of the deeply hooked turtles transmitted less than one month compared to 27% of the lightly hooked turtles, the chi-square test found no significant difference between the transmission distributions for these two categories.

Data was also analyzed to determine whether the length of the turtle (in straight carapace length) played any role in determining differences between deeply hooked turtles and those that were lightly hooked. Only all satellite tagged loggerheads - both with successful tracks and without (n=35) - showed a significant difference (P=0.02) in size between deeply ingested (mean size = 62.0 ± 10.9 cm) and lightly hooked (mean size = 53.0 ± 6.6 cm) (D. Parker and G. Balazs, NMFS, pers. comm., November, 2000).

Studies have also been conducted to systematically evaluate the carcasses of sea turtles which were taken and killed by longline fisheries in the Pacific (*i.e.* turtles came up dead and were collected by the observer). Of eleven turtles (2 greens, 2 leatherbacks and 7 olive ridleys) only one was deeply hooked and many had no visible indication of hooking. From this, it was suggested that because lightly hooked turtles died, deep or light hooking may not be satisfactory criteria to determine the probability of short or long-term survival (Work 2000). However, the author went on to state that "cause of mortality for all turtles was classified as suspect drowning associated with hooking." Had these turtles been able to reach the surface to breathe, and then been released, it is not known how many then would have ultimately died or survived their hooking encounter.

Studies Conducted in the Azores

In 1998, three juvenile loggerhead turtles that had been lightly-hooked by swordfish longline gear in the waters around the Azores were instrumented with satellite-linked time-depth recorders. The number of dives performed by these hooked turtles was compared to five juvenile loggerheads that had been captured by dipnets and instrumented. The turtles that had been caught by longline fishing gear had significantly lower dive counts than turtles caught with dipnets during the time period that normally has the most intense diving activity (from 9:00 am to 3:00 pm; Bjorndal *et al*. 1999).

During a similar study in the summer of 2000, in the same area of the Atlantic, 10 pelagic juvenile

loggerheads were instrumented - four were captured with dipnets (control), and six had been deeply hooked. Results from the summer 2000 study indicated that as of the end of October 2000, two of the four transmitters on control turtles and five of the six transmitters on hooked turtles continued to function. Using criteria similar to the Hawaii-based study for "successful" tracks, one of the control turtles and one of the hooked turtles ceased transmitting within one month after release. In all periods of the 24-hour day (separated by 6-hour increments), the hooked turtles appeared to make longer and shallower dives than control turtles, but overall, dive behavior appeared similar between hooked and non-hooked turtles, having a diurnal component (shallowest dives occurring during 21:00 and 03:00) and a seasonal component (dive depth generally increased for most turtles from summer into fall) (Riewald *et al*. 2000). Riewald *et al.*(2000) opines that transmitters that provide dive profiles are necessary to determine whether transmitter failure is due to mortality or mechanical causes, and describes the diving activity of one of the hooked turtles (still transmitting) as indicative of a dead, floating turtle, buffeted by waves. Caution was given in interpreting both sets of data, as the studies were ongoing at the time of writing.

Estimates of Post-Hooking Mortality

Existing field research into the survival of sea turtles after they have been hooked and released does not provide clear, quantitative patterns (see the preceding section). Other investigators (Aquilar et al. 1995, McCracken 2000) have taken different approaches to estimating rates of injury and death among sea turtles after they have been released from hooks, although these investigations also produced conflicting conclusions

Aguilar *et al*. (1995) reported that 29% of 38 deeply-hooked loggerhead turtles died after swallowing a hook. In every case, they concluded that internal damage from swallowing a hook appeared to be the cause of death. Aguilar also noted that most of these turtles died quickly - within a few weeks - after swallowing a hook (Aguilar, pers. comm. 2001). Six of 38 deeply hooked sea turtles in this study defecated their hooks within 53 to 285 days; most of these turtles survived. (Aguilar, pers. comm. 2001). Finally, 171 externally-hooked loggerheads out of a total of 1,098 loggerheads hooked probably survived. However, in the wild, Aguilar believes mortality of turtles released with a hook inside and trailing monofilament line would be substantially higher than the 20-30% mortality rate for deeply-hooked loggerheads because wild animals would not receive the medical treatment he provided to the animals in his study.

McCracken (2000) tried to estimate the mortality rate for turtles taken by the Hawaiian longline fishery based on data from Aguilar *et al*. (1995) and from information recorded by observers on the condition of the turtles when released (Kleiber 1998). McCracken assumed that none of the turtles that were released uninjured (including *externally* hooked turtles, *e.g*. lightly hooked) died, 29% of the turtles that had ingested a hook (*e.g*. deeply hooked) died, and all of the turtles recorded as dead (*e.g*. drowned or moribund) were dead. McCracken averaged these mortality rates by species and assigned those averages to turtles that were reported as being hooked in an unknown location. For

example, of 147 loggerheads observed taken from 1994-1999, 83 were deeply hooked, 56 were externally hooked (0% mortality rate), 3 were hooked in an unknown location (17% mortality rate), 1 was dead (100% mortality rate), and 1 was of unknown condition (17% mortality rate). By averaging these results, McCracken estimated the mortality of the 147 loggerheads as 17.5%. Balaz (pers. comm. 2001) and Polovina (pers. comm. September 1, 2000) raised questions about McCracken's result by arguing that it may be inappropriate to assume that none of the lightly-hooked turtles die, so this approach may underestimate the true mortality.

In its June 30, 2000, Opinion on the Atlantic HMS Fisheries, NMFS used the mortality estimates provided by Aguilar et al. (1995). Musick (2001) analyzed data collected by NMFS observers and summarized by Hoey (2000), and year 2000 observer reports. Based on his analyses, he challenged NMFS' conclusions and concluded that "it appears that hooking mortality rates of loggerheads may be within the range of 3.3 to 8.6%, and hooking mortality of leatherbacks in this fishery may be nil. These numbers do not suggest a 50 percent mortality rate as assumed by NMFS (in the June 30 Opinion)."

More recently, NMFS recommended that 50% of longline interactions with all species of sea turtles be classified as lethal and 50% be classified as non-lethal (see Appendix 4 of NMFS SEFSC 2001 for a complete review and analysis of relevant research and recommendations). NMFS also recommended revising the scheme for classifying the injuries of sea turtles that have interacted with longline fishing gear have been injured. The new classification scheme is (1) non-serious injuries (2) minor or moderate injuries, and (3) serious injuries that may result in mortality or reduced ability to contribute to the population when released alive after the interaction:

I. Non-serious injuries:
   1. Entanglement in monofilament line (mainlines, gangion line, or float line) where there are no visible injuries (cuts and/or bleeding), the gear is completely removed, and the turtle swims strongly away from the vessel.

II. Minor or Moderate injury:
   1. Visible injuries determined to be superficial and interactions where the gear has been removed and the animal is not weakened (this category would not include ingested hooks under III. 4, below).

III. Serious injuries may result in mortality, or reduced ability to contribute to the population when released alive after the interaction:
   1. Entanglement in monofilament line (mainline, gangion line, or float line) that directly or indirectly interferes with mobility such that feeding, breeding or migrations are impaired.
   2. Entanglement of monofilament line (mainline, gangion line, or float line) resulting in substantial wound(s) (cuts, constriction, bleeding) on any body part.
   3. Hooking external to the mouth resulting in substantial wound(s) (cuts, constriction, bleeding) with or without associated external entanglement and/or trailing attached line.
   4. Ingestion of hook in beak or mouth (visible), with or without associated external entanglement and/or trailing attached line.

5. Ingestion of hook in the mouth, throat area, esophagus or deeper, with or without associated external entanglement and/or trailing attached line.

On January 30, 2001, NMFS Division of Sustainable Fisheries recommended using mortality estimates of 27% for minor and moderate injuries and 42% for serious injuries as appropriate and reasonable risk averse assumptions, given the current scientific information" and suggested using the data presented in Table 7, which were derived from sea turtle satellite tagging studies in the Azores and Hawaii.

Table 7. NMFS Office of Sustainable Fisheries Recommended System for Assigning Mortality to Turtles Taken on Pelagic Longlines

Interaction	Response	Injury	Mortality Rate
Entangled / no hook	Disentangled	No injury	0%
Entangled / external hook	Disentangled, no gear	Minor	27%
	Disentangled, trailing gear	Moderate	27%
	Dehooked, no gear	Minor	27%
Hooked in beak or mouth	Hook left, no gear	Moderate	27%
	Hook left, trailing gear	Serious	42%
	Dehooked, no gear	Moderate	27%
Hook swallowed	Hook left, no gear	Serious	42%
	Hook left, trailing gear	Serious	42%
Turtle Retrieved Dead	- - -	Lethal	100%

Swordfish fishers (Beideman, Budi, pers. comms. 2001) claim significantly higher survival rates for turtles released with ingested hooks than NMFS' recent (or Aguilar's 1995) estimates. The 29% minimum mortality estimate used in NMFS' June 30, 2000, Opinion was universally criticized as too conservative by U.S. longline fishermen present at the January 17-19, 2001 longline gear workshop. Fishermen claimed that few turtles died as a result of their interactions with longline gear and that the percentage of deeply-hooked sea turtles in the U.S. fishery is much lower than those deeply-hooked in the Spanish fishery (less than 12% versus 84%), because of differences in gear types and operating procedures (Budi 2000). However, some fishermen may not recognize that some of the turtles they released alive could die after their release (see previous discussions).

Observations by NMFS observers aboard U.S. pelagic longline boats for the 4th quarter of 2000 indicate that 57% of 21 turtles hooked were released with line still attached, while 43% were dehooked

or released with no line attached. While not disputing that turtles are often released with trailing line, Beideman (2001), representing the Blue Water Fishermen's Association in a letter to NMFS, notes that since NMFS in June 2000 implemented the requirement to use line cutters, the average length of trailing line has been dramatically reduced (83.2% for loggerheads, 70.7% for leatherbacks), and "the lengths of trailing line should continue to diminish, except in cases when the leader breaks while bring the turtle to the boat." Beideman further notes that since the June 2000 requirement for dip nets was implemented, and with fishermen now being instructed to bring turtles aboard whenever possible to remove hooks and lines (as opposed to previously, when they were instructed by NMFS not to bring turtles aboard), "we anticipate that the percentages of boated turtles and those with complete removal of fishing line will increase."

On February 16, 2001, NMFS issued a Decision Memorandum on mortality of sea turtles in pelagic longline fisheries. The Memorandum notes that "the net effect is conservative and therefore meets the ESA criteria of finding on the precautionary side for the animal when there is uncertainty. As better data become available, these estimates can be refined." The following summarizes the recommendation approach for assigning mortalities:

How a turtle is classified		**Assumed Mortality Rate**
A	No hooking, no injury, completely disentangled	0%
B	Hooked externally or entangled, line left on animal (hook does not penetrate internal mouth structure, *e.g.* lip hook	27%
C	Mouth hooked (penetrates) or ingested hook	42%
D	Dead	100%

In the biological opinion on the HMS Fisheries, NMFS assumed that between 29 and 50% of the turtles that have interacted with the longline fishery die from the interaction (*i.e.* including all types of hooking or entanglement encounters, including the range from the "no hooking, no injury, disentangled completely" (0% mortality) category to the "dead" (100% mortality) category, described above.).